

FIG. 2B shows the traces t_{r1} , t_{r2} . . . t_{r6} obtained from receivers R_1 , R_2 . . . R_6 respectively. The line 13 is drawn through the reflections from the interface 12. Because of the anomaly which introduces a longer path through the lower velocity water, the reflections occur at a later time than they would if the anomaly were not present.

FIG. 3 depicts the ray paths from the source S to the receiver R_4 for each of the reflecting interfaces 10, 12, 14 and 15.

FIG. 3A depicts the reflections from each of these interfaces. The reflection 16 has a time error Δ_1 introduced by the anomalous depression 11. Reflection 17 has a time error Δ_2 , reflection 18 has a time error Δ_3 and reflection 19 has a time error Δ_4 . The time error introduced by a surface layer thickness anomaly is time variant; that is, it may increase or decrease with record time. Also, the error spreads across a field section with increasing record time. While the error is most pronounced directly beneath the anomaly at small record times, it spreads across a greater horizontal offset at longer record times. This makes correction of the error difficult, but the present invention can be successfully used to correct for this error.

Referring to FIG. 1, the time section of the surface layer of the field seismogram is migrated by conventional techniques as indicated at 20. The migrated time section is converted into a depth section as indicated at 21. This produces the depth section of the surface and subsurface layers as shown in FIG. 4A. Steps 20 and 21 may be carried out in accordance with the procedure described in Ruehle et al, U.S. Pat. No. 3,671,929. The output of step 4a in that patent is a depth section similar to that shown in FIG. 4A herein. The input used to produce this time section includes the field records and the water bottom time T_w . Water bottom time can be obtained from fathometer readings from marine records. For land records, the travel time through the weathered surface layer is conventionally given in the header of each field record. The migration procedure determines true depth and horizontal offset for each shot point. Then, the depth between the migrated shot points is interpolated to obtain the true depth for each CDP set.

Another depth section is produced in a similar manner as indicated by the steps 22 and 23. In this case, a control layer without the anomaly is assigned to the procedure. Also, the operator assigns velocity. In marine exploration, this will be water velocity, but in land exploration, various velocities may be assigned to produce a depth section of a surface layer without anomalies. The output of these steps is shown in FIG. 5A. Again, steps 22 and 23 are implemented with the procedure of steps 1a through 4a in the aforementioned Ruehle et al patent. The computergraphic techniques described in that patent can be used to assign the control layers and velocity which are necessary to produce the depth section of the desired surface layer.

The depth sections of FIGS. 4A and 5A are converted to the time sections shown in FIGS. 4B and 5B respectively. This is indicated by the steps 24 and 25 in FIG. 1. Again, the procedure described in the aforementioned Ruehle et al patent can be used to generate these time sections. Step 7a in that patent generates a digital time section of reflections. A digital time section of reflections beneath an anomalous surface layer is combined with a digital time section of reflections beneath a desired surface layer to obtain the differences in

reflection times. This step is indicated at 26 in FIG. 1. The result is an array of time corrections Δ_1 , Δ_2 , Δ_3 , and so on, one for each trace. These time corrections are depicted in FIG. 6. They are the differences between the times of reflections of FIGS. 4B and 5B. Similar corrections are obtained for every record time and for every seismic field record. These are stored as indicated at 27 in FIG. 1. The difference matrix includes the time correction and the record time of the reflection to which it applies for each trace of each field record.

The field records, indicated at 28, are time corrected as indicated at 29. Conventional digital time shifting techniques can be used. Conventional CDP processing can then be applied to the time corrected field records as indicated at 30. This processing includes a determination of stacking velocity, normal moveout correction, and stacking.

The effectiveness of the present invention can be seen by comparing FIGS. 8 and 9. FIG. 8 shows the reflections on a field record before the time corrections of the present invention were applied. The anomalous depression 31 in the surface layer results in time anomalies 32-35 in reflections as deep as 3.5 seconds record time. Some anomalous subsurface layering is normally associated with a surface anomaly such as this, but the marked anomalies 32-35 are clearly erroneous. FIG. 9 depicts reflections on the same field record after the corrections of this invention have been applied. The field record now more clearly depicts reflection time and can be used to make a true determination of stacking velocity.

While the invention has been described as applying to marine records, the invention is also applicable to land exploration. One anomalous situation to which the invention is applicable is shown in FIG. 7. In FIG. 7, the wedge 36 has a velocity V_2 which is different from the surface layer which has a velocity V_1 . The subsurface layer has a velocity V_3 which is different from V_1 and V_2 . Time errors resulting from this anomaly can be corrected in accordance with this invention. The depth section produced by the steps 22 and 23 of FIG. 1 is assigned a control layer without the anomaly and a velocity. Then, the time corrections are determined.

While a particular embodiment of the invention has been shown and described, various modifications are within the true spirit and scope of the invention. The appended claims cover all such modifications.

I claim:

1. In seismic exploration wherein seismic energy reflected from subsurface layers is detected to produce seismograms, the method of removing from the travel time of said seismograms the distortion caused by travel through a layer anomaly comprising:

converting said travel time of said seismograms to a depth section of said layers including said anomaly; generating from said seismograms a depth section of said layers without said anomaly;

converting the depth sections to reflection times for each subsurface layer with said anomaly and without said anomaly;

generating time corrections from said reflection times for each trace of said seismograms for each subsurface; and

time correcting said traces with said time corrections at the time of reflection from each of said subsurface layers.

2. The method recited in claim 1 wherein the step of converting said travel time to a depth section includes